CLINICAL COMMENTARY

REACTIVE NEUROMUSCULAR TRAINING: A MULTI-LEVEL APPROACH TO REHABILITATION OF THE UNSTABLE SHOULDER

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ABSTRACT

In this clinical commentary, the use of reactive neuromuscular training (RNT) will be discussed as part of an overall functional rehabilitation program in the treatment of the unstable glenohumeral joint. The RNT program is designed to restore the synchrony and synergy of muscle firing patterns about the shoulder, which are required for dynamic joint stability and fine motor control. Reactive neuromuscular training allows the clinician to bridge the gap between the achievement of clinical based goals and a return to athletic competition. The possible effects of RNT on central nervous system (CNS) programming to establish appropriate reflex responses and functional stability at the glenohumeral joint will be explored. The issues reviewed in this article will highlight the need for future research in this area.

Key Words: reactive neuromuscular training, shoulder instability, central nervous system

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INTRODUCTION

Overhand (baseball, softball) and overhead (swimming, tennis) athletes rely on proper function of the shoulder girdle to allow them to complete the tasks necessary to compete in their respective sports. The shoulder has been measured to move at over 7000 deg/sec and can attain in excess of 16,000 different positions.[1] Due to the inherent instability of the glenohumeral joint and the repetitive nature of many sports, several of these individuals may suffer a shoulder injury at some time in their athletic careers.[2-4] This clinical commentary attempts to provide a theoretical framework describing the use of reactive neuromuscular training (RNT) as part of a functional exercise progression in the treatment of the overhead and overhand athlete with an unstable shoulder.

The concept of RNT was originally proposed by Voight in 1990.[5] The RNT program is the umbrella heading for a variety of rehabilitation techniques designed to restore dynamic stability and fine motor control at an injured joint.[6] The RNT techniques are intended to augment traditional rehabilitation in a complementary fashion via proprioceptive and balance training in order to promote a more functional return to activity.[7] The main objective of the RNT program is to facilitate the unconscious process of interpreting and integrating the peripheral sensations received by the central nervous system (CNS) into appropriate motor responses.[8] The purpose of this article is to describe the possible effects of RNT on CNS programming and the use of various RNT techniques in the rehabilitation of the unstable shoulder. The unstable shoulder refers to a pathologic condition in which unwanted translation of the humeral head on the glenoid causes pain and dysfunction of the shoulder.[9]

PHYSIOLOGY OF PROPRIOCEPTION

Proprioception is a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement (kinesthesia) and joint position (joint position sense).[10] Knowing exactly where the shoulder girdle is in space and how much muscular effort is required to perform a particular action is critical for the successful performance of overhand activities.

Information about the position and movement of the shoulder is available from the peripheral receptors located in and around the articular structures of the shoulder.[11] These specialized receptors provide information to the CNS regarding joint position sense and movement. The mechanoreceptors do this by converting mechanical deformation into electrical impulses that are sent into the CNS.[12] This proprioceptive information, in turn, via descending efferent pathways, influences joint stiffness, coordinated motor patterns, and reflex activity to provide enhanced joint stability.[13]

Both static and dynamic stabilizers serve to provide support to the normal healthy joint. The role of the capsuloligamentous tissues in the dynamic restraint of the joint has been well established in the literature.[14-23] While the primary role of these structures is mechanical in nature, by providing structural support and stabilization to the joint, the capsuloligamentous tissues also play an important sensory role by detecting joint position and motion.[17,24,25] Vangsness et al[26] described the neural anatomy of the glenohumeral ligaments and labrum in the shoulder. They found Ruffini end organs and Pacinian corpuscles in the superior, middle, and inferior glenohumeral ligaments.[26] However, the glenoid labrum contained only free nerve endings relating to the perception of pain. These authors concluded that any disruption of the ligaments by trauma or surgery can deprive the shoulder of mechanical stability, and may cause a decrease in proprioception because of injury to these afferent neural receptors.[26] Sensory afferent feedback from the receptors in the capsuloligamentous structures projects directly to the reflex and cortical pathways, thereby, mediating reactive muscle activity for dynamic restraint.[14,15,17,25] Sensory information is sent to the CNS to be processed and appropriate motor responses are executed. The efferent motor response that ensues from the sensory information, whether volitional or reflex, simple or complex, is called neuromuscular control.[27]

A role for the muscle spindle has also been elucidated. Diederichsen et al[28] found mechanoreceptors in the coracoacromial ligament, the rotator cuff tendons, the musculotendinous junctions of the rotator cuff, and the joint capsule. Joint rotation will stretch one set of muscles and relax another set of muscles.[18] Since the response of the muscle spindle afferents is known to be a function of muscle length, muscle afferents are able to provide an unconfounded, unidirectional signal of movement.[18]

When an athlete moves the glenohumeral joint into external rotation at 90 degrees of abduction, the stretch of the subscapularis causes firing of the muscle spindles. This information is relayed to the CNS regarding position sense and movement. The exact contribution of each of these tissues has yet to be resolved, but information from all locations provides some position and movement sense throughout the total available range of motion.

PATHOPHYSIOLOGY

Following a traumatic subluxation or dislocation, or an atraumatic instability of the glenohumeral joint, disruption to the articular mechanoreceptors inhibits normal neuromuscular reflex joint stabilization.[29-31] Proprioceptive deficits have been uncovered in unstable shoulders in male subjects with unilateral, traumatic, recurrent anterior shoulder instability.[32,33] This partial deafferentation results in a proprioceptive deficit, which contributes to repetitive injuries and the progressive decline of the joint.[32,34] Injuries to the rotator cuff may also lead to a compromise of the afferent feedback from the muscle spindles. Motor programs are adapted to receive specific sensory feedback for the accurate execution of various motor tasks. Injury causes sensory feedback which does not "fit" the existing motor program, causing errors in the normal and coordinated patterns of the muscles and functional joint stability.[35] Ultimately, the individual will be unable to resume high level overhand and overhead activities despite achieving clinical-based goals.

Recognizing the deafferentation of the injured and unstable joint is only half the battle. The rehabilitation specialist must design a program that re-establishes the dynamic functional stability of a joint in hopes of returning the athlete back to competition. Reactive neuromuscular training is employed as part of a functional exercise progression and can be instituted during and following the achievement of clinical-based goals. Before the clinician can utilize these activities, he or she must understand the possible effects RNT has on the CNS.

SPINAL LEVEL

Coordinated movement is made possible by the interaction between multiple subsystems located at all levels of the CNS.[6] Three main levels exist in the CNS- the spinal cord, brainstem, and cortical motor areas.[36] The muscle spindle is the key mechanoreceptor at the spinal level.[37] Afferent fibers from the muscle spindles synapse with spinal interneurons, resulting in an efferent response which causes either facilitation or inhibition of the motor neuron – in other words, a stretch reflex.[37] If an external disturbance, such as an increase in load, lengthens the muscle, the discharge rate of the spindle afferents increases. The stretch produced by the load is counteracted by a reflex contraction maintaining the muscle length close to a set value.[36] The stretch reflex allows muscle tone to be regulated quickly and efficiently without direct interaction by higher neural centers.[36]

MOTOR CORTEX LEVEL

The highest level of the CNS involved in motor control is the primary motor cortex.[36] The CNS can be likened to a highway, with afferent feedback moving north, and efferent feedback moving south. This information travels in parallel rather than series.[36] Coordinating and planning of complex sequences of movement relies on mechanoreceptor feedback to provide conscious awareness of the joint position and speed of the intended movement. The appreciation of joint position sense at the highest or cognitive level needs to be included in the RNT program. Both active and passive joint repositioning can be utilized to enhance cognitive appreciation of joint position.[17] The repetition of these movements will maximally stimulate the conversion of conscious programming to unconscious programming.[1,5,26,38-40] To take this one step further, primary motor cortex involvement occurs in activities that last 300 msec or longer.[36] For example, the pitching motion in baseball, from stride foot contact to ball release takes 0.150 second at the youth and high school level and 0.145 second at the college and professional level.[41] When appropriate, repetition of the correct throwing mechanics allows for the motion to be stored as a central command and be performed without the conscious mind. Since faulty throwing mechanics can contribute to increased distraction of the glenohumeral joint and possibly lead to rotator cuff or labral injury,[42] correct throwing mechanics and repetition of this motion must be part of the overall neuromuscular training program.

The perception of joint position and joint movement sense in the shoulder is essential for the placement of the hand in upper limb function.[6] This perception cannot be accomplished without feedback from the mechanoreceptors and central programming from the motor cortex. The objective of the RNT program is to stimulate the joint and muscle mechanoreceptors to encourage maximal afferent discharge to the appropriate CNS levels. Afferent discharge, will then create an appropriate efferent response at the joint in terms of reflex stabilization and somatosensory perception. Arm movement, reflex stabilization, postural control, and somatosensory perception are not separate events but rather different parts of an integrated action that raises the arm while maintaining balance. A rehabilitation program designed to encourage this feedback will increase the chances of returning an overhand and overhead athlete to their pre-injury level of function.

REHABILITATION

At the present time, no randomized controlled clinical trials exist examining the effects of RNT in the treatment of the unstable glenohumeral joint in the overhead and overhand athlete. However, some guiding principles must be kept in mind when designing the RNT program. The natural progression of these exercises should focus on the continuum of difficulty with respect to the sport or desired activity. These exercises should initially focus on static stabilization of the shoulder joint and progression would then focus on stimulating multiple systems, including vision. Exercises designed to develop dynamic stabilization should progress from bilateral to unilateral, supported to unsupported, and minimal capsular stress to maximal capsular stress.[39] Through therapeutic exercise, the clinician challenges the patient with activities that progress from slow speed to fast speed, from stable surfaces to unstable surfaces, from gradual challenges to sudden challenges, and from simple coordination to complex coordination.

The clinician must be concerned with the kinesthetic input and quality of the movement patterns and not the number of sets and repetitions.[43] It is assumed that the quality of motor control decreases rapidly with the onset of fatigue and the training effects are diminished

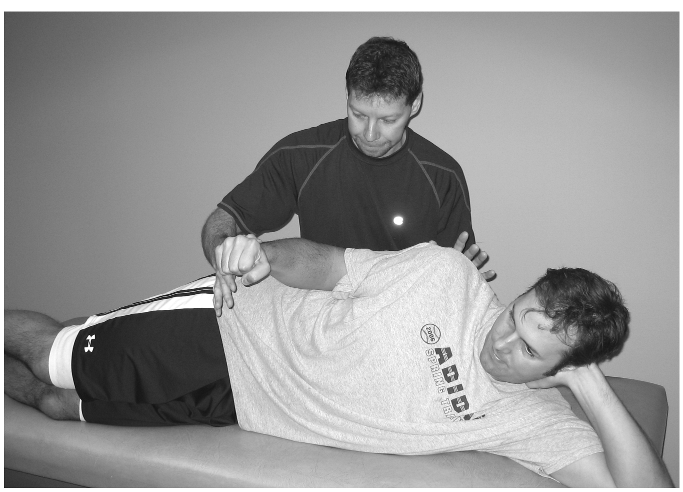

Figure 1: *Rhythmic Stabilization- Patient is sidelying, scapula retracted, upper extremity at side. Therapist moves forearm into ER/IR and pushes scapula toward protraction as patient resists both.*

when the athlete is no longer able to execute the activity. Given that fatigue decreases active and passive joint repositioning,[44, 45] RNT must be fatigue dependent. In order to elicit the appropriate proprioceptive responses, RNT techniques should be applied at the end of the patient's overall treatment program – when fatigue begins, but the quality of movement is maintained. Obviously, not all shoulder injuries are caused by the onset of fatigue. Research has not demonstrated this clinically, but due to the extremely high repetitions that overhead athletes perform in their respective sport, common sense would dictate that fatigue be addressed in a RNT program. Fatigue plays a major role in the loss of dynamic stability and the possible onset of injury.

The RNT program as part of the functional exercise progression initially focuses on dynamic stabilization at the spinal level. Rhythmic stabilization exercises in the open chain position encourage co-contraction of the musculature about the shoulder, providing a foundation for dynamic neuromuscular stabilization.[46] Taking advantage of the stretch reflex, rhythmic stabilization activities create a change in the desired length of the muscle, resulting in reflex muscular splinting. Efficient co-activation restores the force couples necessary to balance joint forces and increase joint congruency, thereby reducing the loads imparted onto the static structures. These activities can be performed early in the rehabilitation program, first in protected positions such as 90 degrees of elevation, again at 45 degrees of abduction, and eventually at the ends of the available range of motion when the glenohumeral joint is more likely to be unstable. Rhythmic stabilization in the plane of the scapula provides joint congruency and appropriate muscle length tension relationships to protect healing structures immediately post-injury or post-operatively *(Figure 1).* As the athlete progresses, more challenging positions include 90 degrees of abduction *(Figure 2)* combined with 90 or more

Figure 2: *Rhythmic Stabilization- Patient is sidelying, upper extremity is at 90 degrees of abduction.*

Figure 4: *Rhythmic Stabilization- Patient is standing, upper extremity is now placed toward maximum external rotation (late cocking).*

Figure 3: *Rhythmic Stabilization- Patient is standing at stride foot contact, upper extremity in the early cocking position.*

Figure 5: *Rhythmic Stabilization- Patient is standing, upper extremity is now placed at the release point.*

degrees of external rotation, and a similar position in standing *(Figure 3-5)*. Raising the arm above shoulder level can induce increased muscle output and places the compromised glenohumeral joint in a sport-specific position. This position replicates the activities performed by overhand and overhead athletes and will undoubtedly create increased mechanoreceptor output and facilitate dynamic neuromuscular stabilization at the spinal level. Load the system with body weight first and then progress to external resistance. In turn, develop the core of the body before the extremity. The onset of tranverse abdominus muscle activity has been documented to occur prior to, or in preparation for, upper extremity tasks.[47]

Simple active and passive joint repositioning, or performing a scapula clock exercise (patient in sidelying, moves the shoulder toward the numbers of a clock, counterclockwise and then clockwise) can enhance somatosensory perception at the motor cortex. The position of the scapula and the scapulothoracic musculature plays a significant role in shoulder stability by providing a stable base of support from which the glenohumeral muscles can fixate and function.[48] The motor cortex also regulates many sports movements that entail controlled acceleration and deceleration.[6] This control makes a case for performing sport-specific plyometric activities near the end of the rehabilitation process when dynamic stability and postural control have been established. Plyometric activities using a weighted ball stimulate unconscious programming as the focus is shifted from holding the arm stable to catching a ball. Movements can be progressed from a supine ball toss and catch in the 90-90 position to kneeling and standing. Eccentric throwing and catching activities enhance joint stabilization while working on deceleration of the upper extremity. These RNT activities are an integral part of the functional exercise progression and will help the athlete return to their pre-injury level of function.

FUTURE RESEARCH

Several areas surrounding RNT need to be addressed to further define the usefulness of this rehabilitation approach. Although this paper describes the use of RNT for an unstable shoulder, these techniques may be useful for any shoulder injury or someone with generalized ligamentous laxity. Secondly, randomized controlled clinical trials investigating RNT are needed to validate this approach. Lastly, objective milestones or outcome measures to better progress patients through the RNT program and determine when it is safe to return to athletic competition are recommended.

CONCLUSION

In this clinical commentary, the use of reactive neuromuscular training (RNT) is discussed as part of an overall functional rehabilitation program in the treatment of the unstable glenohumeral joint. Normal function of the musculoskeletal system requires a complex coordination of functional joint stability and motor control skills. Following injury to the glenohumeral joint, inappropriate or absent mechanoreceptor discharge can alter neuromuscular control resulting in increased risk for re-injury. An RNT program as part of a sport-specific functional exercise progression can re-establish dynamic stability and neuromuscular control. Clinicians can employ these techniques to target specific levels of the CNS to establish appropriate reflex responses and functional stability at the shoulder. Incorporating the principles of an RNT program in the treatment of an unstable shoulder can bridge the gap between traditional rehabilitation and competition, increasing the chances of an athlete returning to their pre-injury level of function.

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